



# Pacific Island Network Vital Signs Monitoring Plan: Phase III Report

## Appendix A: USS Arizona Memorial Resource Overview

Raychelle Daniel (HPI-CESU)

### Pacific Island Network (PACN)

#### **Territory of Guam**

War in the Pacific National Historical Park (WAPA)

#### **Commonwealth of the Northern Mariana Islands**

American Memorial Park, Saipan (AMME)

#### **Territory of American Samoa**

National Park of American Samoa (NPSA)

#### **State of Hawaii**

USS Arizona Memorial, Oahu (USAR)

Kalaupapa National Historical Park, Molokai (KALA)

Haleakala National Park, Maui (HALE)

Ala Kahakai National Historic Trail, Hawaii (ALKA)

Puukohola Heiau National Historic Site, Hawaii (PUHE)

Kaloko-Honokohau National Historical Park, Hawaii (KAHO)

Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)

Hawaii Volcanoes National Park, Hawaii (HAVO)

<http://science.nature.nps.gov/im/units/pacn/monitoring/plan/>

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*Organization contact information:*

National Park Service (NPS), Inventory and Monitoring Program, Pacific Island Network, PO Box 52, Hawaii National Park, HI 96718, phone: 808-985-6180, fax: 808-985-6111, <http://science.nature.nps.gov/im/units/pacn/monitoring/plan/>

Hawaii-Pacific Islands Cooperative Ecosystems Studies Unit (HPI-CESU), University of Hawaii at Manoa, 3190 Maile Way, St. John Hall #408, Honolulu, HI 96822-2279

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## **EXECUTIVE SUMMARY & INTRODUCTION**

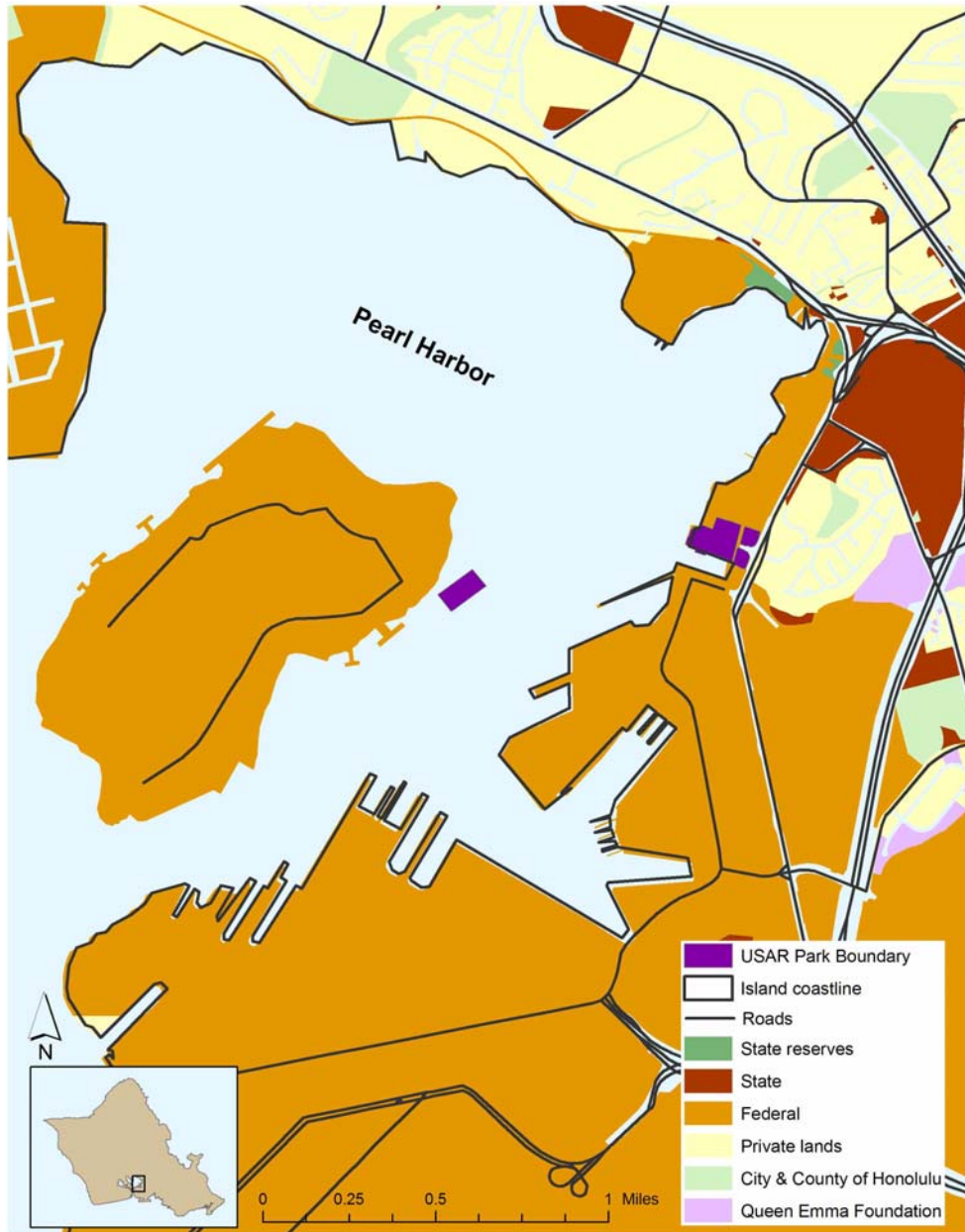
### **Enabling Legislation**

A congressionally authorized enabling mandate does not exist for the USS Arizona Memorial (USAR). The 1978 Military Construction Authorization provided for the transfer of the operation of the USS Arizona Memorial from the United States Navy to the National Park Service (NPS) at the completion of the Visitor Center. This transfer of operation was agreed upon by the Secretary of the Navy, Middelndorf, and Acting Secretary of the Interior, Frizzell, in 1975. It was finalized through an interagency agreement between the U.S. Navy and the NPS in October 1980.

To find enabling legislation documents on-line follow the “Policy & Legislation” link from the Pacific Island Network website ([www1.nature.nps.gov/im/units/pacn](http://www1.nature.nps.gov/im/units/pacn)).

### **Geographic Setting**

Pearl Harbor, on the south-central side of the Island of Oahu is a large estuarine environment comprised of three larger lochs (East, Middle and West) and one smaller loch (Southeast) that are all separated by a narrow channel to the open ocean. The memorial is located in the East Loch, immediately east of Ford Island (see map below). The USAR boundary contains 450 meters of coastline, 5.5 submerged acres (including 100 feet around the USS Arizona), and 11 acres on land. The surrounding area is one of the most densely populated areas in the State of Hawaii with numerous attractions drawing thousands of people per day. The park is situated entirely within active U.S. Naval Reservation boundaries which includes residential areas Ford Island, U.S. Navy recreation facilities, and U.S. Navy dock facilities. Pearl Harbor contains several protected and designated areas. Pearl Harbor National Wildlife Refuge, with a 37-acre unit in the West Loch (Honouliuli) as well as a 25-acre unit in Middle Loch (Waiawa), is managed by the U.S. Fish and Wildlife Service (USFWS). Aiea Bay State Recreation Area, located in the East Loch, is managed by the State of Hawaii. Pouhala Marsh, 70 acres of wetland sanctuary in the West Loch, is managed by the State of Hawaii.



### **Significant Natural and Cultural Resources**

The primary resource in the park is the submerged wreck of the battleship USS Arizona which entombs sailors and marines killed in the December 7, 1941 attack on Pearl Harbor. A 184-ft memorial structure now spans the wreck and serves as a platform to receive visitors. These structures provide habitat to many encrusting filter-feeding organisms such as sponges, bryozoans, annelid worms, mollusks, and tunicates, as well as filamentous diatoms, and green, brown and red algae. Water quality is also an important or focal resource for the perpetuation of this park and its significant cultural resources, including the hull of the USS Arizona.

### **Resource Management Priorities**

The park commemorates all civilian and military personnel killed in the Pearl Harbor attack, and management efforts focus on respectful maintenance of the memorial function. There are several hundred thousand gallons of Bunker C fuel oil encased in the hull of the USS Arizona which may potentially be catastrophic if released. Environmental management for such an event is addressed by the U.S. Navy as part of their regular port operations. The hull is probably the best studied example of metallurgical decay in a marine environment. The NPS monitors basic marine environmental parameters as part of their ongoing hull curatorial efforts. Land use and harbor practices have significantly altered the physical and chemical properties of the harbor area as well as drastically modified the flora and fauna present.

## NATURAL RESOURCES

### Focal Ecosystems and Processes

- Marine Landscape: The USS Arizona as habitat for fauna and flora
- Invertebrate and Algal Community Diversity
- Urbanized Streams
- Water Quality
- Threatened & Endangered Species: *Chelonia mydas* and *Monachus schauinslandi*

**Marine Landscape:** The primary resource in USAR is the sunken WWII battleship, the USS Arizona, which has come to serve as important habitat and substrate for many marine species. Additionally, the live encrusting organisms provide structural rigidity and act as reinforcement for the hull, potentially minimizing its collapse. In addition to providing substrate, the ship provides habitat for a diverse assemblage of fish. Henderson (1986) observed 25 species of fish in the vicinity of the ship. It is likely that there are more species in the vicinity of the vessel.

**Marine Invertebrate & Algal Diversity:** The sunken vessel provides substrate for many encrusting filter-feeding organisms such as sponges, bryozoans, annelid worms, mollusks, and tunicates as well as filamentous diatoms, and green and red algae. These organisms (both live and dead) comprise over 99% of the cover of all vertical surface area (Henderson 1986). Hard corals were not observed in the park during the mid-late 1980s (Henderson 1986) or in recent years by park SCUBA divers. Hard corals were, however, observed on the northeast side of Ford Island (Coles 1999).

**Streams:** Several highly urbanized streams flow into Pearl Harbor. Halawa stream empties into Pearl Harbor near the visitor center. Other streams that flow into the East Loch include Kalauao and Waimalu Streams. The Waiawa is also in the watershed that empties into the Middle Loch.

**Water Quality:** Water quality is an important resource. Sedentary organisms depend on water conditions since they can not easily move when it degrades. A number of streams flow into Pearl Harbor, and since the quality of this water influences both corrosion rates and the condition of the sedentary organisms existing on the hull of the ship, it is an important resource to monitor.

**Threatened & Endangered Species:** *Chelonia mydas* (green sea turtle), federally listed as threatened under ESA, have been observed in park waters resting on the sunken vessel. *Monachus schauinslandi* (Hawaiian monk seal), federally listed as endangered, have been observed swimming around the sunken vessel.

### Threats & Stressors

- Potential Hull Failure
- Degraded Water Quality from: Oil Spills, Land-based Runoff & Contaminants
- Alien and Invasive Species
- Litter
- Unexploded Ordinance
- Discharge of hazardous gases from the hull
- Natural Stressors

***Potential Hull Failure:*** The compartmentalized hull contains several hundred thousand gallons of Bunker C fuel oil. There is concern that the ship may disgorge a large quantity of fuel oil into Pearl Harbor. Depending upon environmental conditions, this oil may significantly impact most of the park's submerged resources, and will also have significant ramifications outside the park boundary.

***Degraded Water Quality:*** The industrialized nature of Pearl Harbor and its adjacent land use practices are major contributors to water quality in the harbor. Two major oil spills have occurred within Pearl Harbor, one in 1987 with over 100,000 gallons of aviation fuel spilling into Middle Loch, and one in 1996 with 39,000 gallons of bunker fuel spilling into East Loch (Coles et al. 1997). Both spills affected the park's marine or adjacent nearshore resources including invasive mangroves, intertidal organisms, and water quality. Water quality is also affected by polluted run-off, sediment, and debris. More than 75 feet of silt sits on the bottom of the harbor. Silt can be re-suspended and settle on the hull, degrading water quality and impacting marine life. Water quality in the marine environment is also degraded by contaminants and heavy metals leaching from land fill and dredge disposal sites.

***Alien and Invasive Species:*** The Bernice P. Bishop Museum documented Pearl Harbor as a major entry point for marine invasive species to the Hawaiian Islands (Coles et al. 1999, Godwin 2003, DAR 2003). These species have been well documented, including those on the USS Arizona itself (DAR 2003). Pearl Harbor's invasive species are a significant and currently unmanaged problem of ample magnitude. Not only are invasive species a problem in the marine environment, but also in the Pearl Harbor watershed, where 60% of 329 estuarine and riparian species were determined to be invasive, 19% were undetermined, leaving only 21% native (Englund et al. 2000).

***Litter:*** Staff at USAR clean litter from the deck of the USS Arizona every two weeks. The more than 1.5 million people that visit this park each year contribute to the litter problem. Many visitors leave coins in the water and the effect of these metal pieces on the decay rate of the sunken vessel is not known. Tourists visiting the vessel routinely drop objects over the side of the Memorial, including items such as sunglasses, cameras, and batteries. Furthermore, large rainfall events flush litter from nearby streams onto the sunken vessel.

**Hazardous Gases:** Methane and other gases have been released from the USS Arizona. The source of these gases is unclear, but may be related to decomposition of bacteria (possibly oil-consuming bacteria) inside the hull.

**Unexploded Ordinance:** In addition to the primary cultural resources of the park being relic military equipment, munitions and other explosives are often found in and around the sunken vessel.

**Natural Stressors:** Natural stressors that could affect the sunken vessel and its inhabitants include changes in the physical environment from sea level rise, storm surge and current dynamics. These environmental parameters may also be heightened by global climate change. Seismic activity (including tsunamis) could affect USAR, but is less likely to occur due to the shape and location of the harbor entrance and its proximity to the opening in the channel reef.

### **Water Quality Designations**

In Hawaii, water bodies are classified by their designated use according to the Hawaii Revised Statutes, Section 11, Chapter 54 which contains definitions and water quality standards for each water body type with respect to desired uses. Waters which do not meet the criteria for their designated uses are considered non-supportive and, if certain conditions are met, may be reported as impaired to the Environmental Protection Agency as per requirements of the Clean Water Act, Section 303(d). Groundwater designations are being developed by the state of Hawaii, but are not available at this time. The marine waters and benthic ecosystems of Pearl Harbor are classified as “A” and “II”, respectively, protecting their use for recreational and aesthetic enjoyment by regulating discharges and human alteration. The marine waters of Pearl Harbor are listed as impaired due to exceeding the water quality standards for nutrients, turbidity, suspended solids, and polychlorinated biphenyls (Hawaii State DOH 2004). Therefore, at USAR no water bodies are listed as unique or pristine. The Hawaii State Department of Health water quality standards are available at <http://www.hawaii.gov/doh/rules/11-54.pdf> and the 2004 303(d) list for Hawaii is posted at <http://www.hawaii.gov/health/environmental/env-planning/wqm/wqm.html#303pcd>.

## **CULTURAL ISSUES**

- December 7, 1941 Pearl Harbor Attack
- Historic Fish and Shellfish Use

**December 7, 1941 Pearl Harbor Attack:** “Because the sunken hull of the USS Arizona remains in place, and its 1,177 casualties accounted for almost half of all the casualties sustained that day, it became the symbol of commemoration and place of remembrance for the December 7, 1941 attack. Though the exact number is not known, the remains of approximately 900 to 1,000 crewmembers were never recovered and remain entombed within the ship's hull” (NPS 1992). Any management action affecting the entombed crewmembers will be given serious consideration and thought. Natural resources, including both water quality and encrusting



organisms (i.e., invertebrates and algae) are important components of the sunken vessel and act to provide stability to the hull; however, the metal hull may continue to decay in its aqueous environment. Because of Pearl Harbor's historical significance, USAR gets a high recreational visitation rate, with over one million visitors annually, since 1982<sup>1</sup>. In 2003, 1,476,396 people passed through the front gate at USAR.

***Historic Fish and Shellfish Use:*** Historically, Pearl Harbor was known for fishing and shellfish collecting. One of its original Hawaiian names, Wai Momi, meaning “water of Pearl” or “river of Pearl”, infers abundant shellfish. Another historic Hawaiian name known for Pearl Harbor estuary was Puuloa, which was regarded as the home to Kaahupahau (the shark goddess) and her brother Kahiuka.

In Hawaiian belief schooling aweoweo or Big eye (*Heteropriacanthus cruentatus*), which is deeply red in color, foretells the eminent death of a chief. Around the time that King Kalakaua died, large schooling behavior of aweoweo occurred in Pearl Harbor (Hoover 2003).

## MANAGEMENT ISSUES

### Park management

“The National Park Service manages and operates the USS Arizona Memorial under a Use Agreement with the U.S. Navy. The USS Arizona Memorial lacks specific authorizing legislation, as a unit of the National Park Service, in which its purpose is stated. Public Law 85-344, approved March 15, 1958, authorized construction and maintenance of the USS Arizona Memorial and a museum. Public Law 87-201, approved September 6, 1961, authorized an appropriation for the construction and maintenance of the USS Arizona Memorial and a museum ‘in honor and in commemoration of the members of the Armed Forces of the United States who gave their lives to their country during the attack on Pearl Harbor, Hawaii, on December 7, 1941.’ On March 21, 1980, a Use Agreement was signed with the U.S. Navy authorizing the National Park Service to operate the USS Arizona Memorial complex. This Use Agreement did not elaborate on the Memorial's purpose” (NPS 1992). Furthermore, “under the Use Agreement with the U.S. Navy the National Park Service was given responsibility for the USS Arizona Memorial, but not the sunken hull of the USS Arizona. As the major historic resource of the area the National Park Service has, on its own initiative, assumed unofficial responsibility for the ship.” Due to the nature of this park, there are no General Management Plans but there is a Statement of Management for the park

Management objectives as noted in the Statement for Management of the USS Arizona (NPS 1992) that pertain to natural resource management issues include two management objectives. The first objective is to “Preserve the USS Arizona Memorial as a tribute to the military casualties of the Pearl Harbor attack.” The second is to “provide for the preservation of the sunken hull of the USS Arizona.” Since the USS Arizona is a sunken

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<sup>1</sup> NPS online statistics, <http://www2.nature.nps.gov/stats/>

vessel, water quality affects its condition, as do the invertebrates and algae that have colonized and incorporated into the hull.

Other NPS natural-resource related documents include a report from a cultural study of the submerged resources in Pearl Harbor (Lenihan 1990) and a report from a resource monitoring program (Russell and Murphy 2004).

Park management documents (General Management Plan, Resource Management Plan, etc.) are available on-line at the NPS intranet site ([www1.nrintra.nps.gov/im/units/pacn/parks/mgmt\\_docs.htm](http://www1.nrintra.nps.gov/im/units/pacn/parks/mgmt_docs.htm)). This website is available only from NPS computer networks. Inquiries about public access should be directed to the park.

***Leak Detection & Decay Rate:*** Management issues at USAR are focused on the preservation and management of the ship as an important archaeological resource and memorial. An important and unresolved issue is the threat of oil discharge from ship compartments, creating a need for leak monitoring and detection. The sunken vessel also provides an opportunity to study the metallurgical decay and encrustation rate of ship wrecks in the marine environment. Future actions are geared towards monitoring the physical and chemical decay processes in the shallow marine environment.

***Marine Invertebrate and Algal Communities:*** The sunken vessel has provided habitat for many encrusting marine organisms that have contributed to the hull's structural rigidity. These organisms face potential threats from impaired water quality, pollution, and runoff. Since enabling legislation requires monitoring and preservation of the USS Arizona, the marine environment and organisms that have attached themselves to the vessel also must be maintained and monitored. The effect of invasive or alien organisms on this community is not known.

***Sedimentation:*** Pearl Harbor receives large quantities of sediment from streams and runoff. More than 75 feet of silt sits on the bottom of the harbor. Silt can be re-suspended and settle on the hull, degrading water quality and impacting the marine life.

***Contaminants:*** An area of concern is contamination of water quality from surrounding industrial activities and urban stream runoff.

## INVENTORIES

### **Existing Inventories in Park**

***Marine Communities - Invertebrates & Algae:*** In a survey of the “biofouling”, sedimentation and corrosion of the USS Arizona, Henderson (1986) created a checklist of common organisms observed on or around the hull of the sunken vessel. He found 25 taxa of encrusting organisms and 25 species of fish. Particularly abundant were sponges, (*Schizoporella errata*), annelids (*Branchiomma cingulata*, large sabellids, and *Salmacina* spp.), molluscs (Vermetids and oysters), solitary and colonial tunicates, filamentous red

and green algae, as well as diatom mats. No hard coral species were observed. Photo slides were taken for any future biological monitoring studies.

### **Priorities for New Inventories in Park**

***Marine Communities - Invertebrates, Fish & Algae:*** Comprehensive and updated inventories of invertebrates, algae and fish present at USAR are needed. The only study within USAR that provides a partial checklist of fish and invertebrates was conducted during the mid 1980s (Henderson 1986). This brief survey included only major species that were readily identifiable; and did not identify rare, microscopic or cryptic organisms. Some of the organisms included in the checklist were identified to genus.

***Marine Communities – Monk Seals & Sea Turtles:*** No formal surveys of marine mammals and sea turtles have been conducted, but reliable incidental observations have been made by park staff.

***Freshwater Communities – Fauna:*** The marine larval stages of native amphidromous species may also be present in the harbor waters, however, significant restoration efforts would likely be required for the streams in the East Loch watersheds to provide satisfactory adult habitat.

### **Buffer Zone Inventories**

***Marine Communities:*** The first comprehensive biological inventories of marine benthos in Pearl Harbor were conducted by the Navy Undersea Center during 1970-1972 (Evans et al. 1974). A shoreward piling, located approximately 300 feet from the USS Arizona Memorial, was included in their study. This site is representative of the area around the memorial, and is characterized as having vertical substrate with rocks, mud ledge and debris in its vicinity along with sand, mud and silt bottom approximately 30 feet below the surface. Included in this study were fish surveys, micro mollusk surveys, piling surveys of marine organisms on vertical surfaces at two depths (0 and 10 feet), and benthic surveys. Other data collected during this study included physical and chemical measurements of sediment, water quality, tidal movement, and runoff measurements.

A total of 388 taxa were observed in Pearl Harbor during these studies including 23 species of algae, 278 species of invertebrates and 87 species of fish. In the benthic surveys 114 taxa were identified. Sediment samples of micromolluscs resulted in 37 species identified with *Hiatella hawaiiensis*, *Odostomia oodes*, *O. indica*, and *Crepidula aculeate* the most widely distributed within Pearl Harbor. A total of 88 genera and 113 taxa were identified in the piling surveys. Commonly observed species/families in Pearl Harbor included *Hiatella hawaiiensis*, *Syllidae*, *Cirratulidae*, *Crepidula aculeate*, *Pilumnus oahuensis*, *Styela* sp., *Vermetidae*, *Elasmopus rapax*, *Balanus amphitrite*, *Ophiactis savignyi*, and *Bugula* spp.

The study site (piling ~300 feet) closest to the USS Arizona Memorial site had 30 species identified (with a mean of 185 individuals per sample). The predominant algae observed

at this piling was *Caulerpa verticillata* while polychaetes and decapods were the faunal organisms most commonly observed. The USS Arizona site was described as having “very soft mud with Vermetid tube debris.”

The Bishop Museum recently conducted comprehensive marine, freshwater, and estuarine invertebrate inventories for Pearl Harbor. Englund et al. (2000) and Coles et al. (1997) provide background and historical documentation of environmental changes and biological studies occurring throughout Pearl Harbor. The survey sites in the 1996 Bishop survey (Coles et al. 1997) included the same stations surveyed by Evans et al. (1974) during the 1970s. These sites included a station adjacent to the USS Arizona memorial and one at the northeast part of Ford Island. Coles et al. (1997) observed a total of 419 species throughout Pearl Harbor, including 36 species of algae, 1 spermatophyte, 323 invertebrates and 59 fish species. This most recent inventory combined with past surveys totals to 1123 taxa for Pearl Harbor (Coles et al. 1997). A significant observation in this study was that 95 of the species observed were either introduced or cryptogenic. Another significant observation made during this study was five species of hard corals were documented at 8 sites in Pearl Harbor (Coles et al. 1997). The comprehensive inventories conducted during the 1970s detected no hard coral species (Evans et al. 1974). The most commonly observed coral was *Leptastrea pupurea*, which also occurred at the northeast end of Ford Island (Coles et al. 1997). *Pocillopora damicornis* was found near the Navy Shipyard, on the opposite shore of the memorial (Coles 1999). Reducing non-point source runoff contributes to more favorable conditions in water quality that allow for more sensitive species such as hard corals.

***Freshwater & Estuarine Communities:*** In October 1997 to August 1998, the Bishop Museum studied aquatic insects, fish, crustaceans and molluscs in representative major streams and wetlands that empty into Pearl Harbor. They described riparian vegetation, stream substrate, and habitat condition for each study site. In the East Loch they surveyed Halawa, Aiea, Kalauao Stream, Kalauao, Waimalu and Waimano streams and springs. In the Middle Loch they surveyed Waiawa Stream, Waiawa Refuge, Waiawa Spring and Eo Stream. They found the majority of these species identified to be alien invasive species. The majority of these species are believed to originate from aquarium, intentional biocontrol and intentional food source released species. Mangroves, an invasive species that has significantly altered the environment in Pearl Harbor, have continued to spread within the watershed. In the appendix to the report, they provide a listing of occurrences of freshwater and estuarine organisms that have ever been collected or observed in Pearl Harbor.

## MONITORING

### **Existing Monitoring in Park**

***USS Arizona Long-term Management Strategies Research Project:*** Currently the NPS Submerged Resources Center (formerly the Submerged Cultural Resources Unit), along

with USAR, is examining how natural processes affect the structure and integrity of the sunken ship (Russell and Murphy 2004). The aims of this project are to minimize environmental hazards in Pearl Harbor from oil leakage and to provide baseline information that could be used to make informed management decisions in stance with historical preservation of the tomb. Many of these studies are conducted in collaboration with other departments (e.g., Department of Defense, U.S. Geological Survey [USGS]) and institutions (e.g., Medical University of South Carolina).

***Hull Integrity – Corrosion potential, pH and hull thickness:*** The integrity of the hull is being monitored by measuring the corrosion process in situ. Measurements are also done using x-ray diffraction and scanning electron microscope techniques on hull samples collected from the vessel at different depths and exposures. Preliminary results indicate that corrosion rates are greatest near the top of the hull (at waterline) decreasing to below the mudline (Russell and Murphy 2004). On-going studies are now focused on assessment of corrosion and bacterial activity within the sunken vessel and below the mudline.

***Water Quality – Baseline Environmental & Oceanographic Data:*** USGS scientists Drs. Mike Field and Curt Storlazzi placed instruments on the seafloor near the USS Arizona to collect baseline environmental data. Data collected include wave and current patterns as well as pH, temperature, salinity, dissolved oxygen, oxygen reduction potential and conductivity. Their aim is to determine patterns of these variables in Pearl Harbor over a two-year period and identify any correlations with corrosion rates. To date, 14 months of data have been collected and the next step is to correlate these results with other studies examining hull integrity and the finite element model (Storlazzi et al. 2004).

***Finite Element Model (FEM) Development:*** Mathematical modeling of the hull life is being conducted (with NPS-SRC and USAR) by Drs. Tim Foecke and Li Ma of National Institute of Standards and Technology (NIST) in Maryland (Russell and Murphy 2004). Modeling will incorporate the parameters on hull thickness and corrosion rates. The models will help analyze possible management implementation scenarios. Predictive models examine different outcomes on the hull in the areas that contain the fuel oil with different degrees and types of stress acting on the hull. The blast that initially sank the vessel will also be modeled.

***Oil and Microbiological Analysis:*** The possibility of using microorganisms in fuel oil degradation is being examined in collaboration with Dr. Pam Morris of Medical University of South Carolina (Russell and Murphy 2004). Samples of oil, sediment, water, and concretion are being collected as a part of this study and will be used to determine the state of deterioration and structural change of inaccessible oil bunkers.

***GPS Structural Monitoring & Geological Studies:*** GPS (Global Positioning System) points are being collected to detect hull movement. Initial points were collected in June 2001 with the most recent resurvey in November 2003 (Russell and Murphy 2004). Baseline studies on geological stability are also being carried out by NPS and USGS around the vicinity of the USS Arizona. Stratigraphy, grain size, and structural

characteristics of sediment will be examined from geological core samples taken at four locations. Field data collected in these studies, as well as the ship plans and photographs, are being incorporated into a GIS (Geographic Information Systems) databases.

***Other Baseline Information:*** USAR dive staff regularly inspects the sunken hull for signs of oil seepage. The interior of the sunken vessel was also investigated with a VideoRay ROV (Remotely Operated Vehicle) to search for access to oil bunkers, level of interior deterioration, and to collect environmental samples including pH, temperature, salinity, dissolved oxygen, oxygen reduction potential, and conductivity.

### **Priorities for New Monitoring in Park**

***Marine Communities:*** Marine invertebrate and algal community structure are a priority for natural resource monitoring, particularly because of their role in assisting with structural rigidity of the hull.

***Invasive Species:*** The presence of invasive species and their effect on the present community structure is not known. If these species persist, they could affect community structure and potentially disturb the organisms that have been incorporated into the hull.

***Water Quality:*** Continued and more in depth water quality monitoring is needed for this park. Water quality is an important facet, both biologically and structurally.

### **Buffer Zone Monitoring**

***Stream Monitoring – DOH:*** The State of Hawaii Department of Health (DOH) monitors local streams for land-based run off and discharge into the Pearl Harbor watershed. Parameters include temperature, dissolved oxygen, pH, nitrogen, phosphorus, turbidity and flow rates.

***Stream Monitoring – USGS:*** The USGS-WRD monitors discharge and gage height in Halawa Stream (gage #16226200) which flows into the East Loch of Pearl Harbor adjacent to the USAR visitor center.

***Water Quality Monitoring – Outfall Monitoring by Navy Environmental:*** The Navy Environmental program monitors water quality at the outfall from the Fort Kamehameha Wastewater Treatment Facility for temperature, ammonia, nitrate/nitrite, total nitrogen, total phosphorus, turbidity, chlorophyll a, salinity, dissolved oxygen and pH. After qualifying rainfall events, storm water runoff is monitored at eight industrial sites in and around the Pearl Harbor Naval Compound. Depending on the industrial activities in the drainage area being sampled, analytes may include aluminum, arsenic, cadmium, chromium, copper, total cyanide, iron, lead, magnesium, mercury, nickel, selenium, silver, titanium, zinc, MBAS, chemical oxygen demand, biological oxygen demand, total suspended solids, total dissolved solids, ammonia, nitrate/nitrite, total nitrogen, total kjeldahl nitrogen, total phosphorous, pH, specific conductance, oil and grease, total

petroleum hydrocarbons (THP), THP as gasoline, THP as diesel, total fuel hydrocarbons, and 21 organic compounds.

**Water Quality Monitoring – USEPA:** The USEPA implemented the Hawaii EMAP in 2002 which included 1 randomly selected site in Pearl Harbor's Middle Loch. Sample locations in the 2002 assessment were limited to embayments. Sampling will begin again in early 2005 at a new set of randomly selected locations that will include open coastal areas as well as embayments.

**Water Quality Monitoring – Leeward Community College:** Pearl Harbor Watershed Environmental Restoration Projects contracted water quality studies by Leeward Community College (LCC) from April 18, 2000 - December 31, 2001. From 1979 to 1994, LCC students of Donald G. Klim studied water quality parameters at different locations throughout Pearl Harbor from Waiawa stream to West Loch.

**Geologic monitoring** – Tide gauges located on the islands of Oahu, Kauai, Maui and Hawaii record fluctuations in local sea level and analysis of these records provides rates of long-term sea level variation around the state. Results show that each island has its own rate of relative sea level rise due to the local isostatic response.

**Marine Monitoring – Brock Surveys:** Brock (1994, 1995) monitored fish and epibenthic fouling organisms on or near Hawaii Electric Company Waiau discharge on the West side of Ford Island and at the head of Aiea Bay.

## CONCLUSIONS

Designated as a national memorial, management efforts focus on the respectful maintenance of the memorial function. Primary natural resources include the benthic marine community (comprised primarily of invertebrates and algae) on the ship hull as well as water quality. Primary threats to resources include increasing urbanization, invasive species, and chemical water and soil contamination. The sunken hull provides an excellent example of *in situ* observation for ship wrecks and decay. Future management at USAR is aimed towards continued monitoring of the sunken hull and simultaneous development of strategies (i.e. will preserve without endangering the tomb) to avoid major catastrophic release of fuel oil.

## REFERENCES

- AECOS. 1987. Preliminary assessment of the biological impact of the May 13, 1987 fuel spill on the mangrove environment in Middle Loch, Pearl Harbor, Hawai'i AECOS 495: Chevron, Inc.
- Apple, R.A., Kikuchi, W.K. 1975. Ancient Hawai'i shore zone fishponds: an evaluation for historical preservation: U.S. National Park Service.

- Brock, R.E. 1994. An analysis of benthic communities in the zone of mixing for the Waiau Electrical Generation Facility JA619: Hawai`ian Electric Co.
- Brock, R.E. 1995. An analysis of benthic communities in the zone of mixing for the Waiau Electrical Generation Facility Year 2 report - 1994 JA619: Hawai`ian Electric Co.
- Coles, S.L. 1999. Colonization of reef corals in Pearl Harbor, Oahu, Hawaii. *Coral Reefs* 18:28.
- Coles, S.L., Defelice, R.C., Eldredge, Lucius G., Carlton, J.T. 1997. Biodiversity of marine communities in Pearl Harbor, O`ahu, Hawai`i with observations on introduced exotic species. Final Report prepared for the U.S. Navy, Bishop Museum Technical Report No. 10: Bernice Pauahi Bishop Museum Hawaii Biological Survey, Bishop Museum Press.
- Englund, R.A., Preston, D.J., Wolff, R., Coles, S.L., Eldgredge, L.G., Arakaki, K. 2000. Biodiversity of freshwater and estuarine communities in lower Pearl Harbor, Oahu, Hawaii with observations on introduced species. Final Report prepared for the U.S. Navy, Bishop Museum Technical Report No. 16: Bernice Pauahi Bishop Museum Hawaii Biological Survey, Bishop Museum Press.
- Evans, E.C. (1974). Pearl Harbor biological survey: final report. Prepared for the Naval Undersea Center, San Diego, California. 800 pp.
- Evans, E.C., Murchison, A.E., Peeling, T.J. & Stephen-Hassard, Q.D. (1972). A proximate biological survey of Pearl Harbor, O`ahu. Prepared for the Naval Undersea Research and Development Center, San Diego, California. 65 pp.
- Grovhoug, J. G. 1992. Evaluation of sediment contamination of Pearl Harbor Rept. no. NRAD-TR-1502: Naval Command, Control and Ocean Surveillance Cent.
- Hawaii State DOH 2004. Final 2004 List of Impaired Waters in Hawaii. Prepared under the Clean Water Act Section 303(d) by Hawaii State Department of Health Environmental Planning Office. 67 pp.
- Henderson, R. S. 1986. A survey of the biofouling, sedimentation, and corrosion status of the USS Arizona: Naval Ocean Systems Center. Hawaii Laboratory.
- Hoover, J.P. 2003. Hawaii's Fishes: A guide for snorkelers and aquarists. Mutual Publishing, Honolulu, Hawaii. 183pp.
- Johnson, D. L., J. D. Makinson, R. de Angelis, B. Wilson and W. N. Weins. 2003 Metallurgical and Corrosion Study of Battleship USS Arizona, USS Arizona Memorial, Pearl Harbor, Hawaii. University of Nebraska, Lincoln.
- Lenihan, D. J., Delgado, J. P., Dickinson, B., Cummins, G., Henderson, R. S., Martinez, D. A., Murphy, L. E. 1990. Submerged cultural resources study: USS Arizona Memorial and



- Pearl Harbor National Historic Landmark, Southwest Cultural Resources Center professional papers: U.S. National Park Service. Southwest Cultural Resources Center.
- Makinson, J. D., D. L. Johnson, M. A. Russell, D. L. Conlin and L. E. Murphy. 2002 In Situ Corrosion Studies on the Battleship USS Arizona. *Materials Performance* 41(10):56-6.
- National Park Service. 1996. Waiau oil spill 5/14/96: U.S. National Park Service.
- National Park Service. 1996. Waiau oil spill, May 14-17, 1996 : the photographic documentation of the effect & closure of the USS Arizona Memorial Visitor Center: U.S. National Park Service.
- National Park Service. 1992. Statement of Management USS Arizona Memorial July 1992, National Park Service, Department of the Interior. 39pp.
- Russell, M. A., and Murphy, L. 2004. Long-Term Management Strategies for the USS Arizona: A Submerged Cultural Resource in Pearl Harbor, Hawaii. National Park Service Submerged Resources Center and USS Arizona Memorial Legacy Resources Management Fund Project No. 03-170;2003 Annual Report. Technical Report No. 15 Submerged Resources Center Intermountain Region National Park Service Santa Fe, New Mexico
- Storlazzi, C.D., Russell, M.A., Owens, M.D., Field, M.E., and Murphy, L.E. 2004. Dynamics of the physical environment at the USS Arizona Memorial: 2002-2004. U.S. Geological Survey Open-File Report 2004-1353.
- S.O. Hirota Inc. 1977. Environmental impact assessment: USS Arizona Memorial: U.S. Navy. Pacific Division Naval Facilities Engineering Command.
- Youngberg, A.D. 1973. A study of groundwater contamination beneath landfills at Pearl Harbor EPDB 73-004 LIMDIST: U.S. Navy. Pacific Division Naval Facilities Engineering Command.